

ETO Switch Development for Power Conditioning

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DOE Energy Storage Program Peer Review 2004

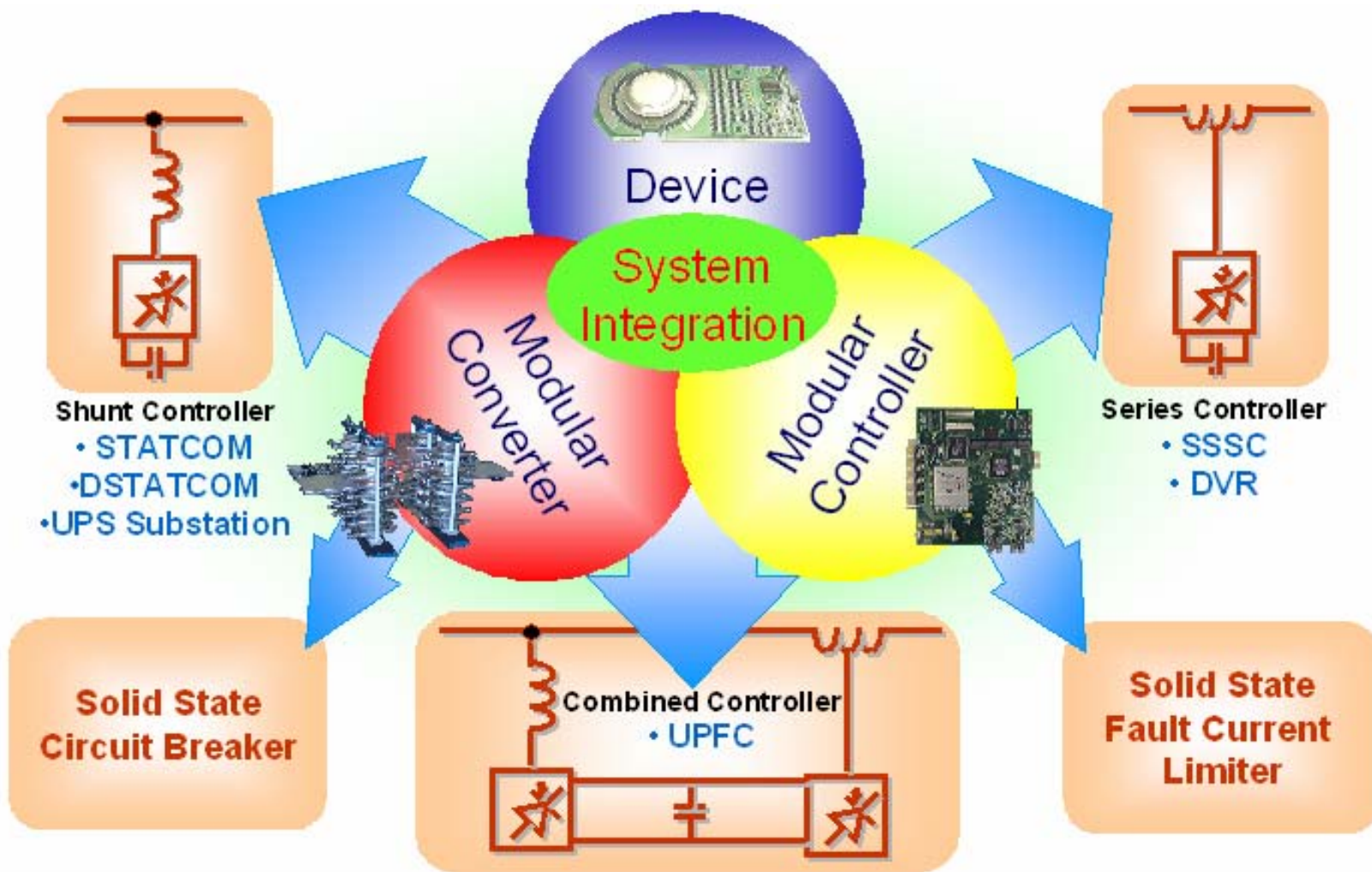


**Sandia
National
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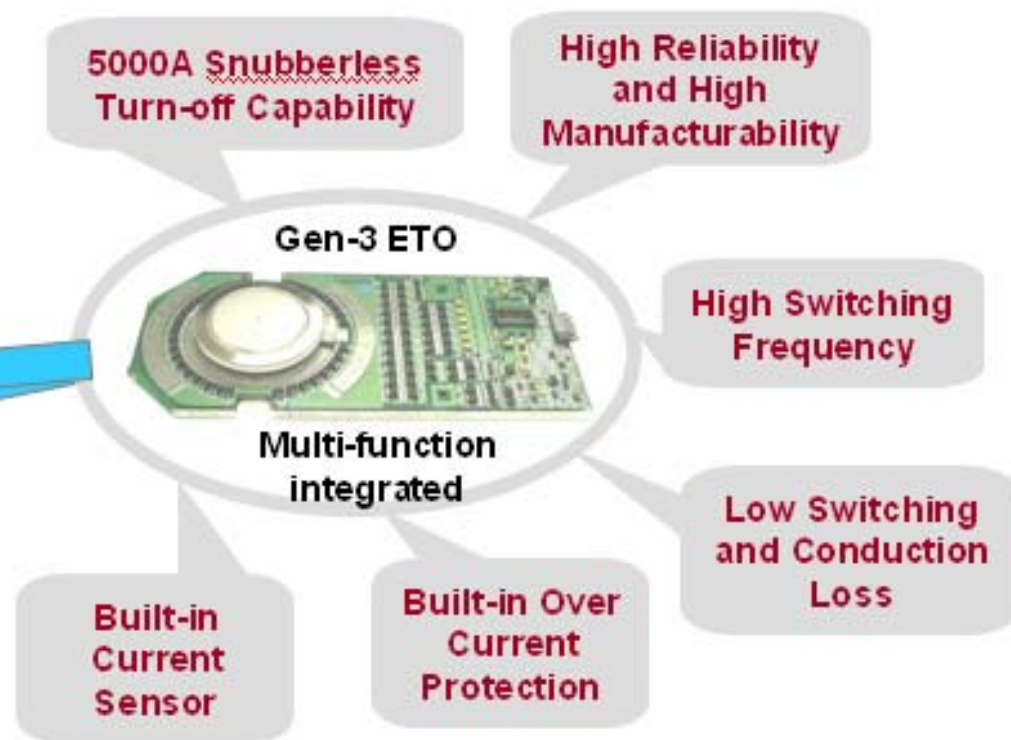
- Power Semiconductor Devices (PSD)
 - Power Management Microsystems (PMM)
 - Utility Power Electronics (UPE)
 - Electric Power Systems (EPS)
-
- Three faculty members
 - 20+ graduate students
 - 8000 sq. ft of lab space



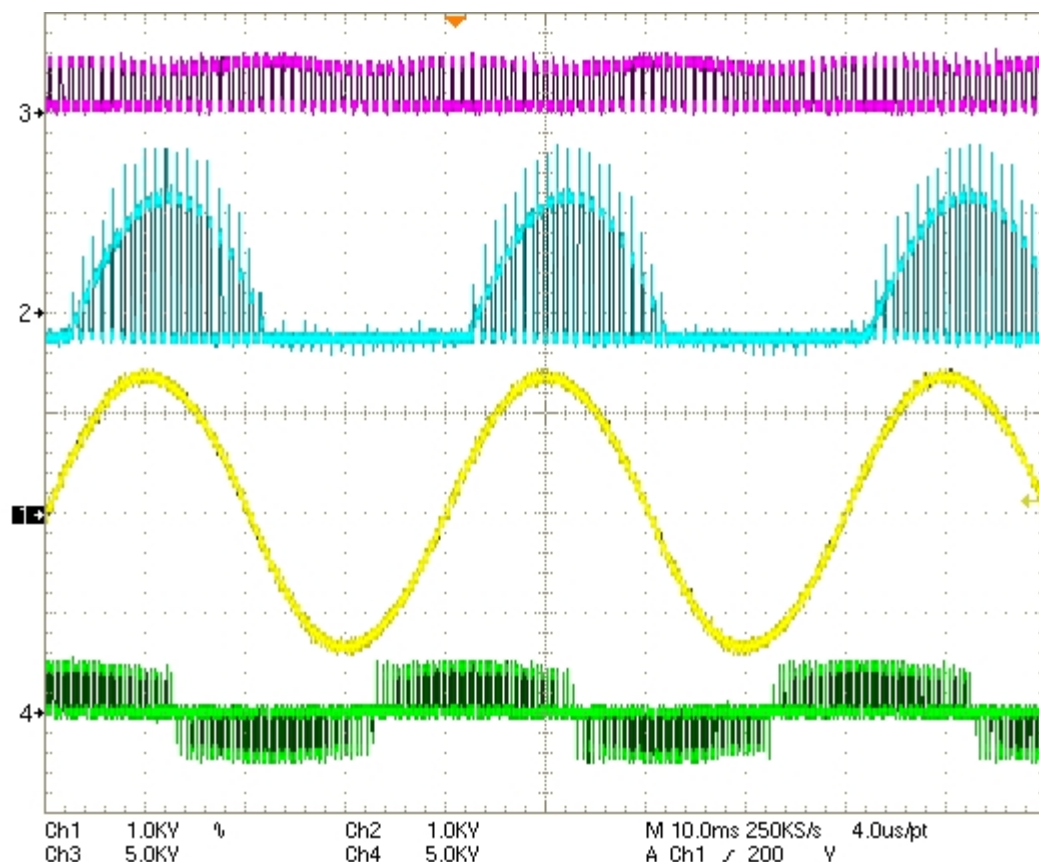


- **FY2004 Activities and Accomplishments**
- **Applications and Insertions of ETOs**
- **Future Works**

Gen-3 ETO: the Advanced High Power Switch for Voltage Source Converter



- Easy for series and parallel operation
- Application scope: Distributed Energy Resources, FACTS, Energy Storage, Traction, Motor drive, Power system protection



S₁ switch voltage
(5 kV/div)

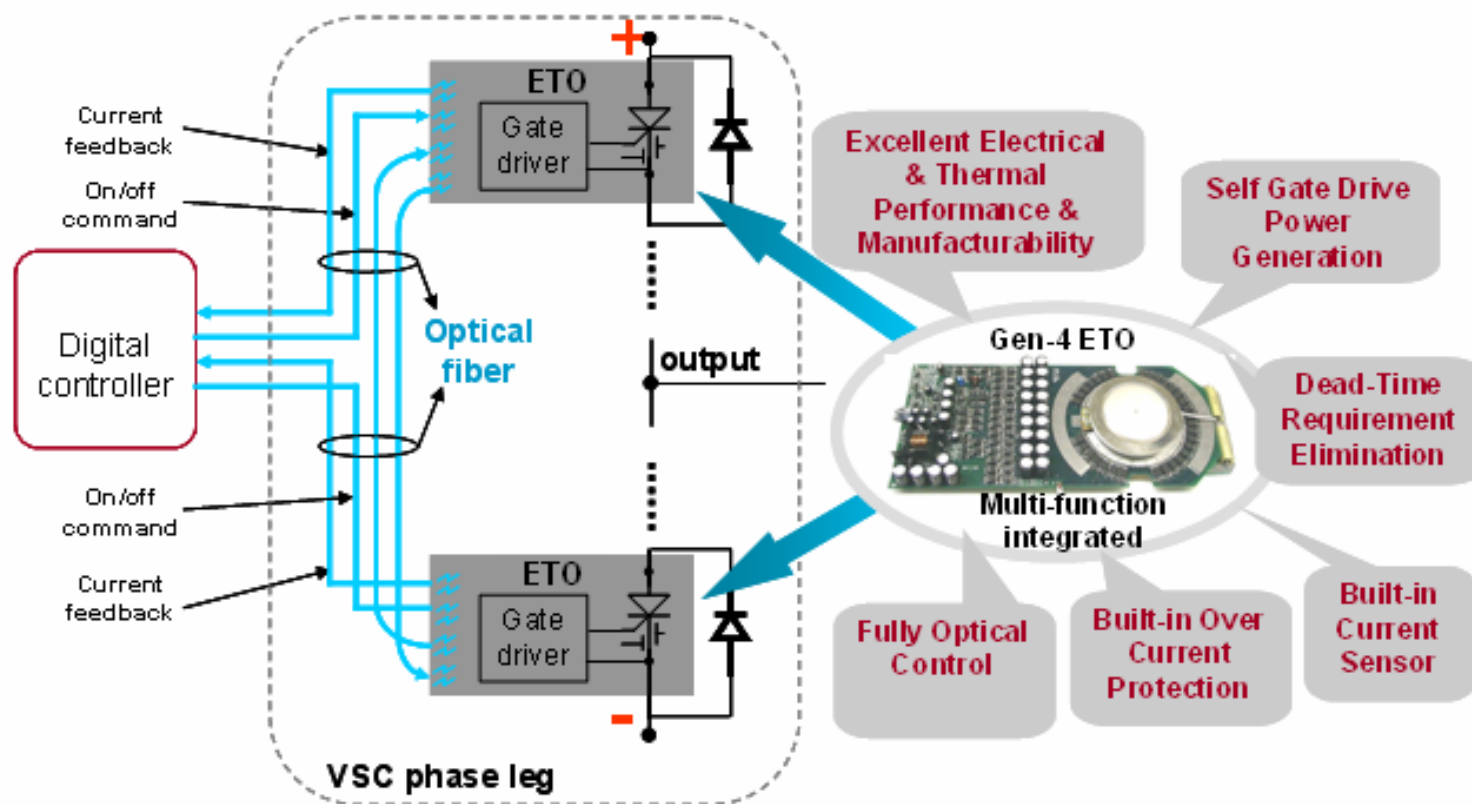
S₁ switch current
(1 kA/div)

Load current
(1 kA/div)

Load voltage
(5 kV/div)

Test conditions: Line frequency: 25 Hz, Switching frequency: 1 kHz, M=0.9
DC Bus voltage: 2 kV, Output RMS current 1.0kA

Gen-4 ETO: the Next-Gen High Power Switch with Fully Optical Control

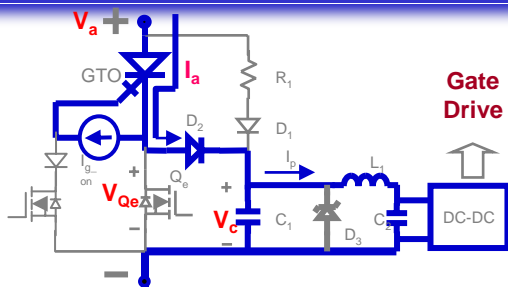


- High power density, high performance
- Simple Construction

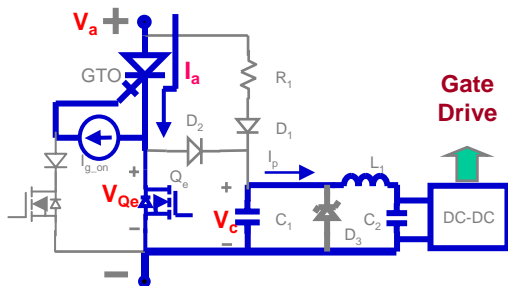
- Low cost
- High reliability

The Experimental Demonstration of the Self-Power generation function of the Gen-4 ETO

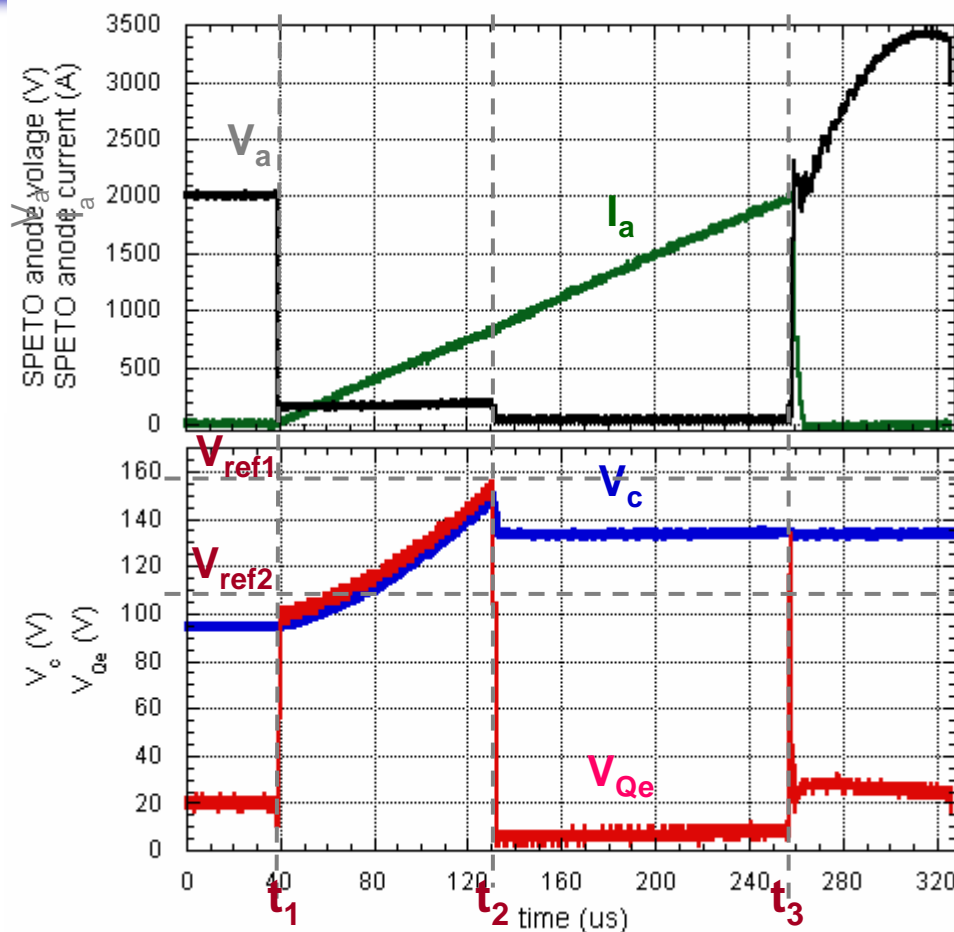
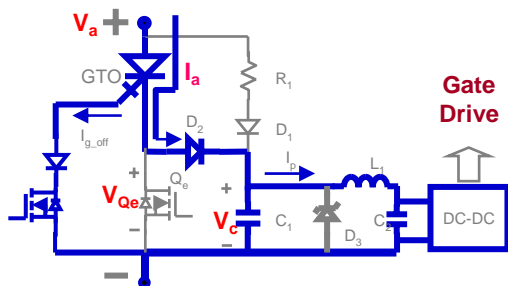
t1:
SPETO charge
turn-on



t2:
SPETO
normal
on-state

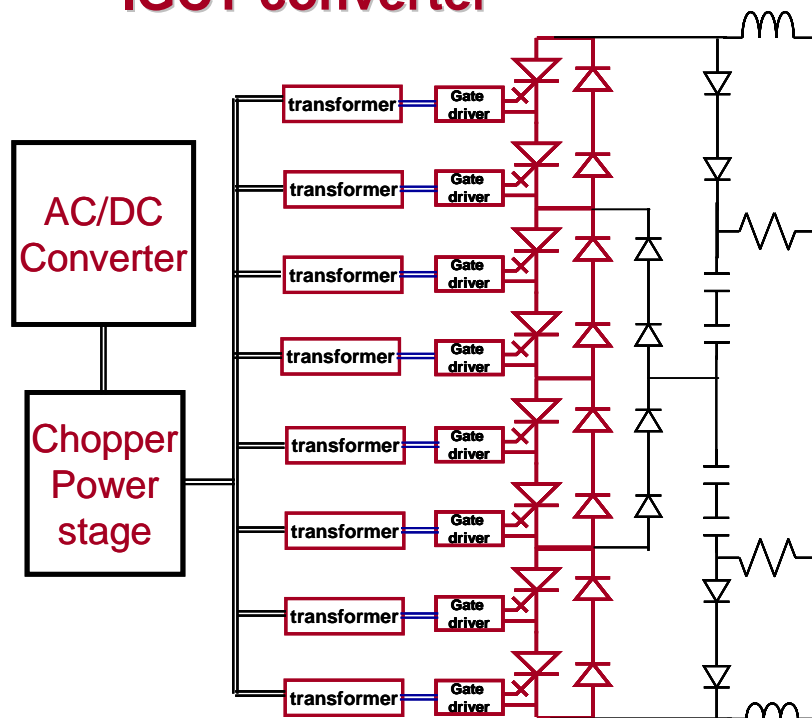


t3:
SPETO
turn-off

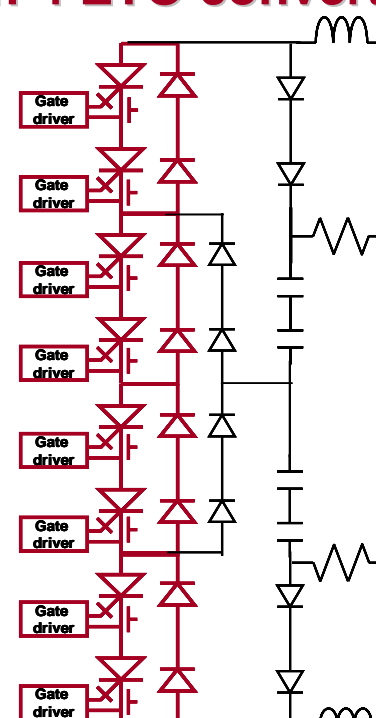


- ETO obtains 10.1J in this switching cycle
- The energy can provide the ETO's gate drive for about 1s switching at 1000Hz

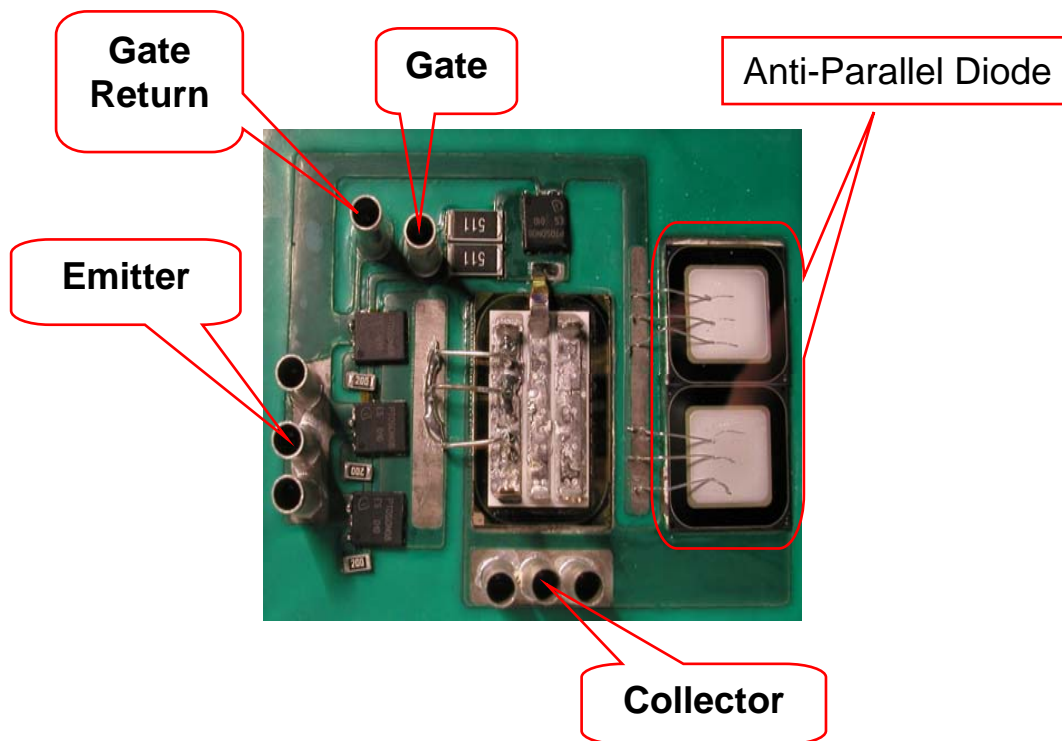
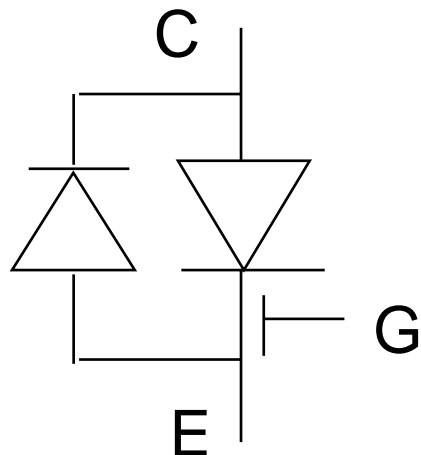
IGCT converter



Gen-4 ETO converter

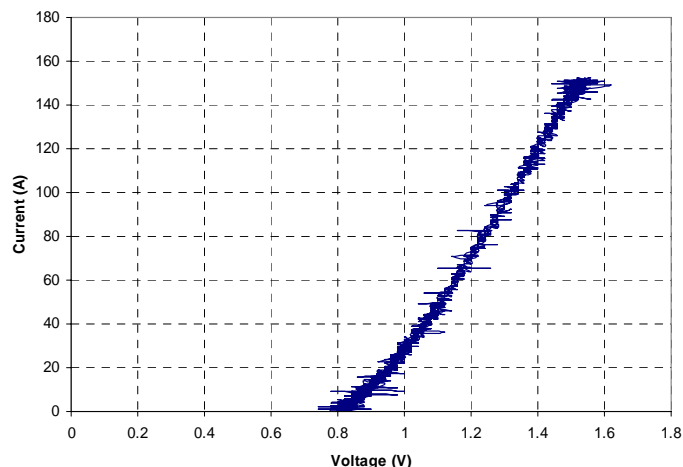


- Gen-4 ETO will greatly simplify the converter structure
- User interface is like a Light Triggered Thyristor (LTT)
- The reliability is increased and the cost is reduced
- Extremely important for series operation

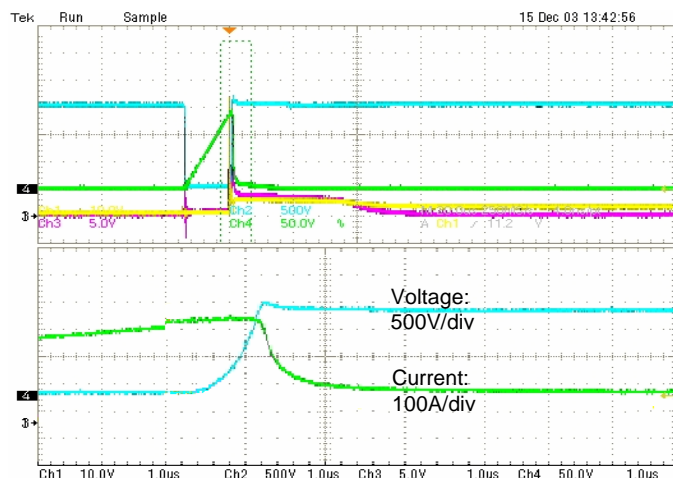


- 5 kHz operation
- Planar GTO as main switch
- Packaged on isolated substrate
- Current rating scalable

On-state characteristics

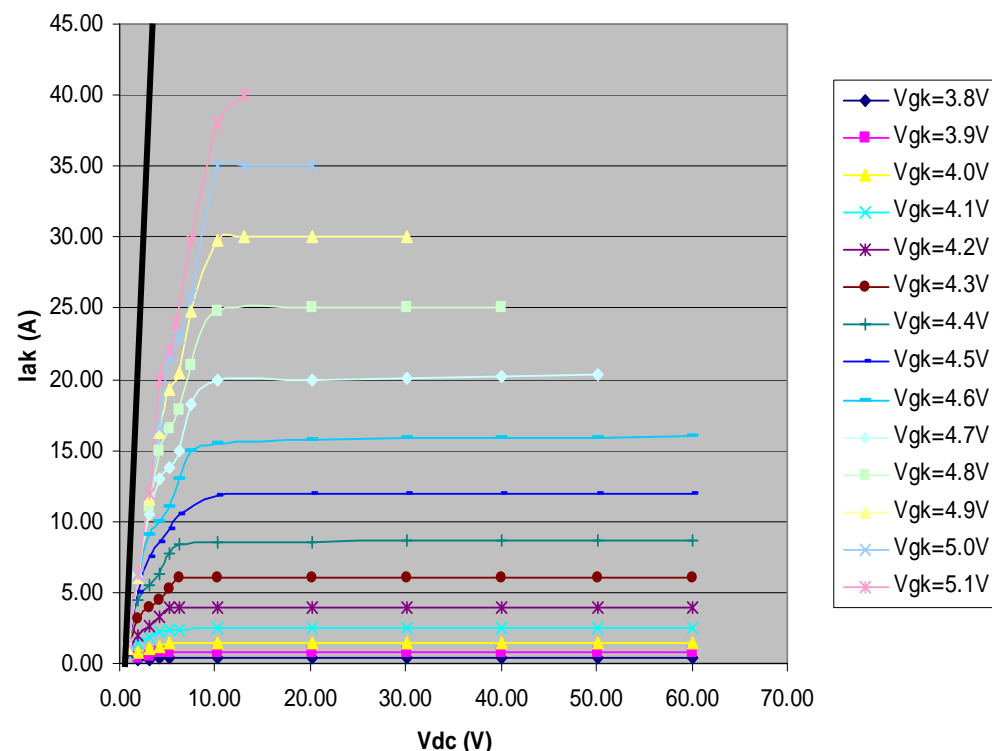


Snubberless turn-off waveforms

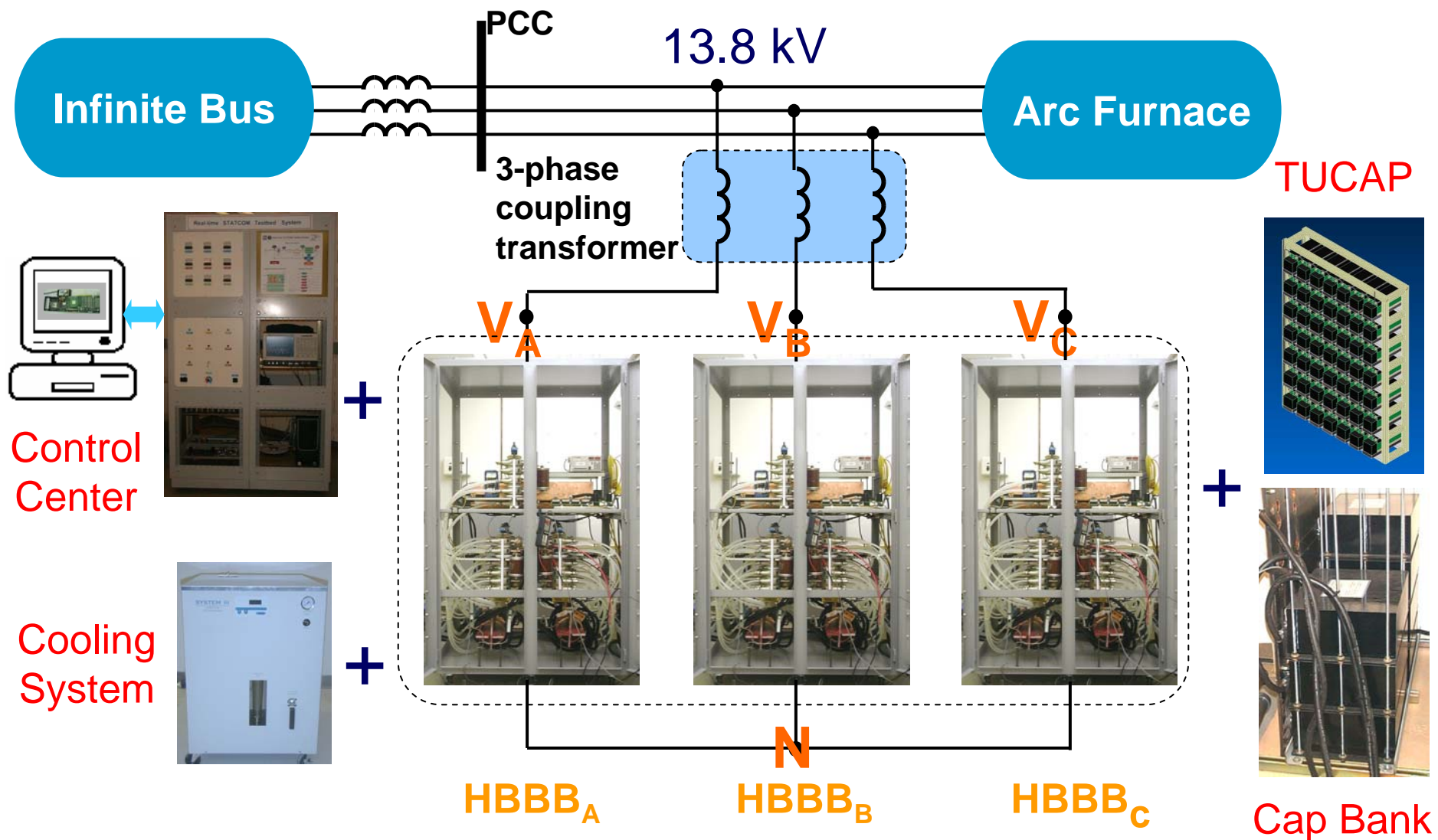


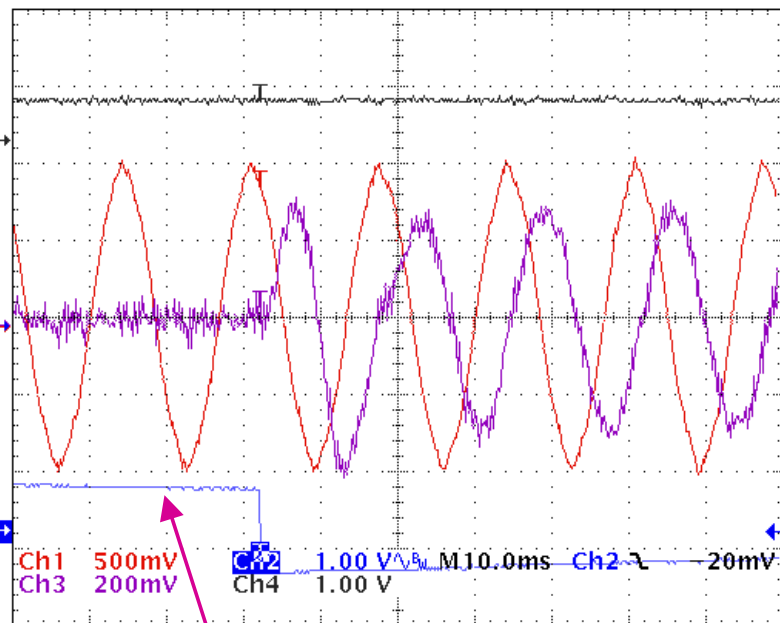
Demonstration of forward-bias SOA

I-V curve



- Low conduction loss
- Snubberless turn-off capability
- Turn-on di/dt controllable





← DC Bus of Phase A

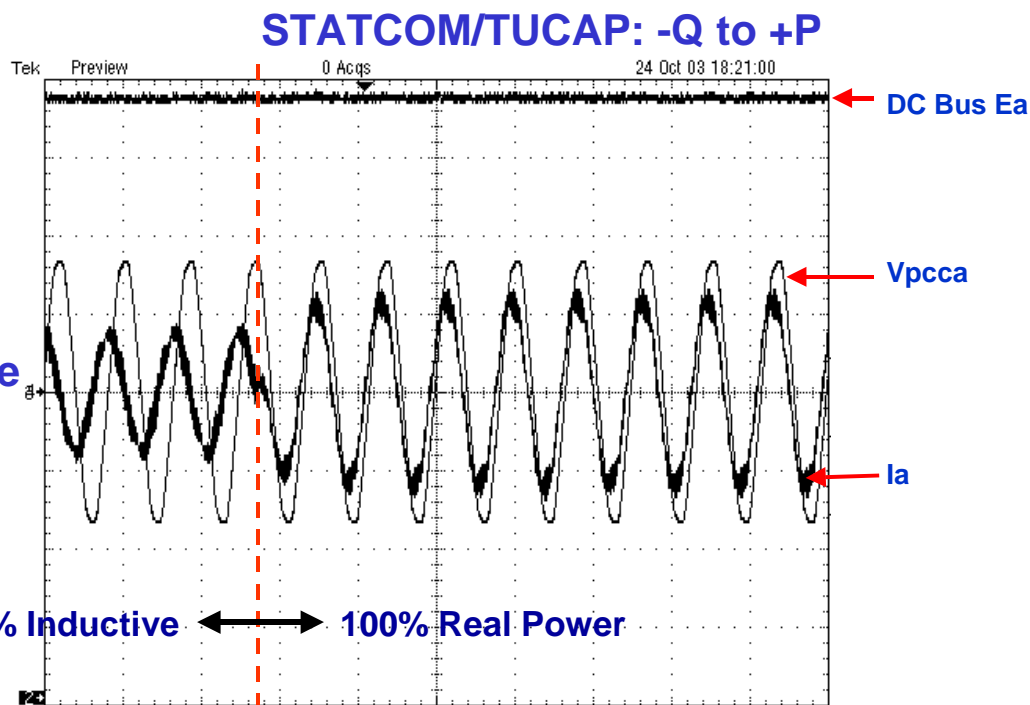
← Vpcc AB

← Output current of Phase A

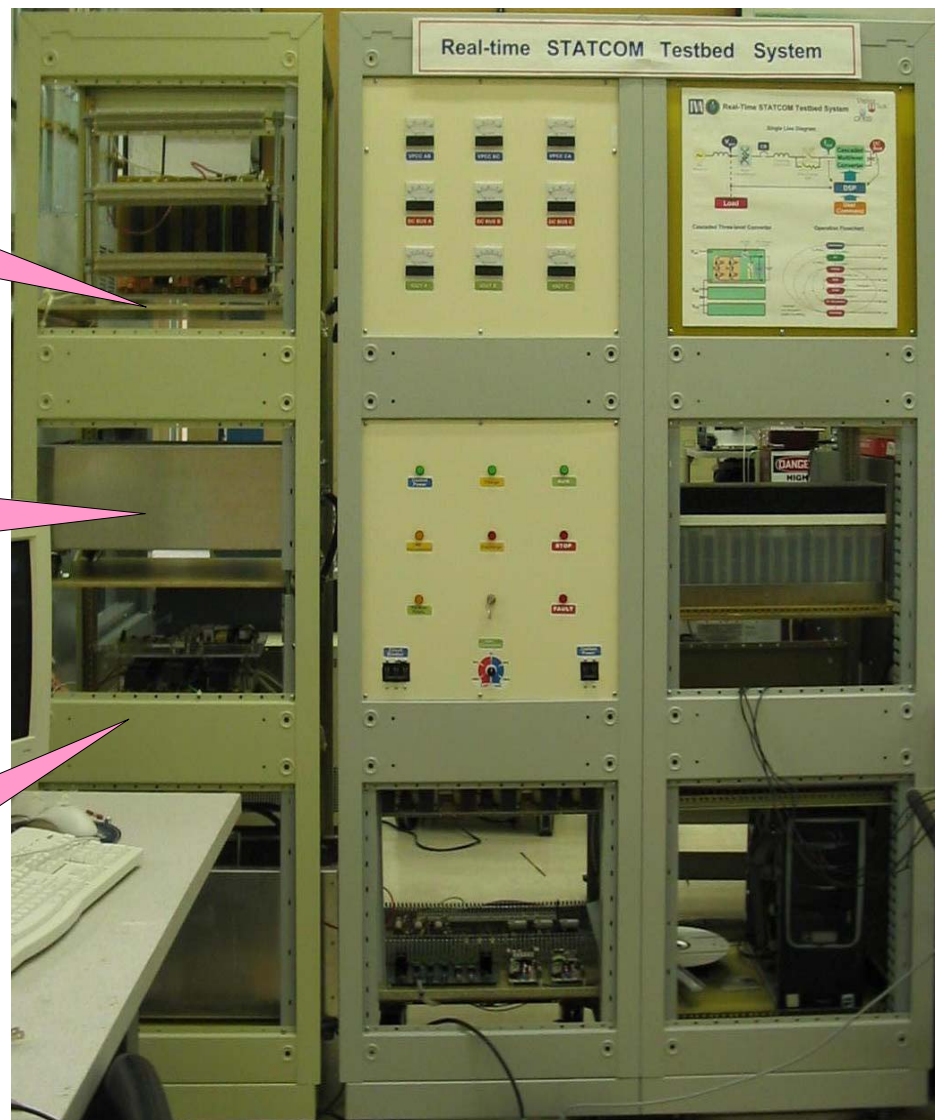
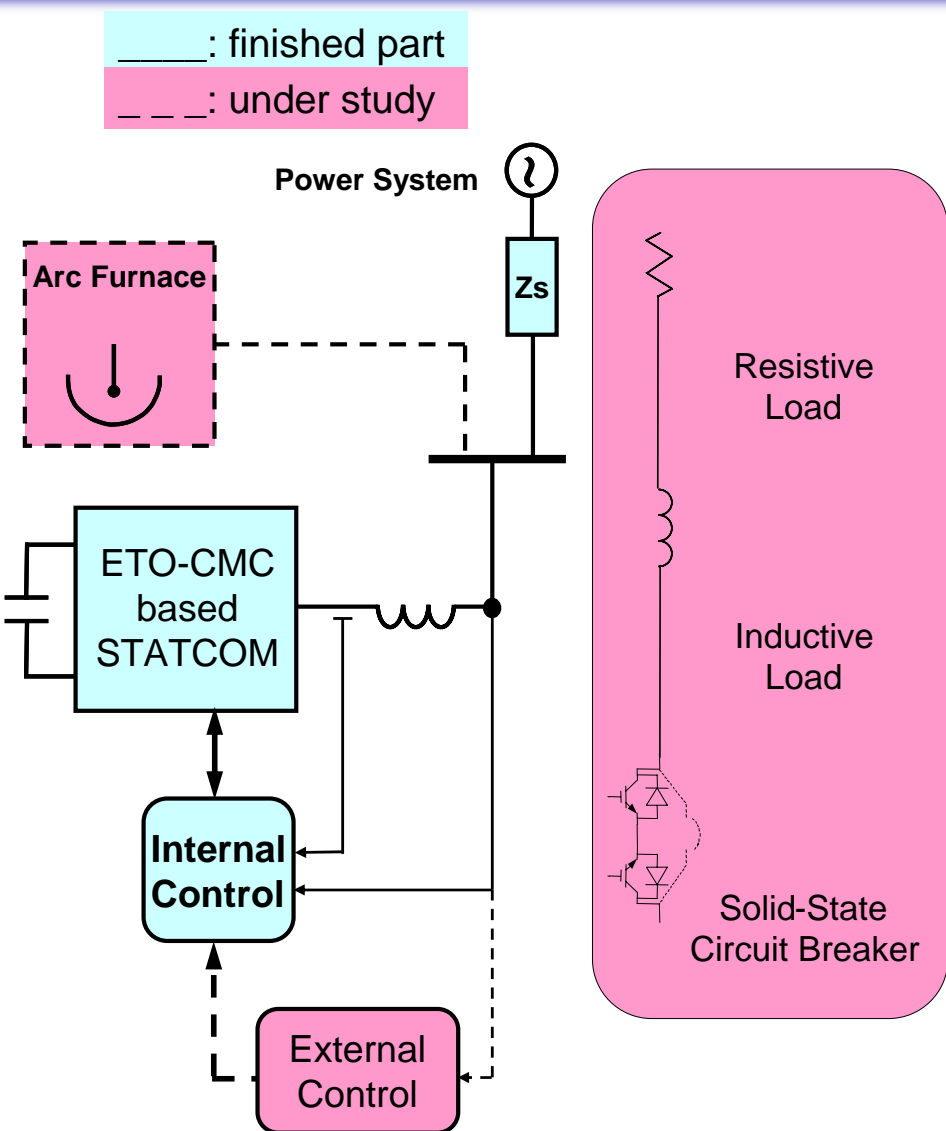
STATCOM: Standby to Full-Capacitive Mode

IQ_Command

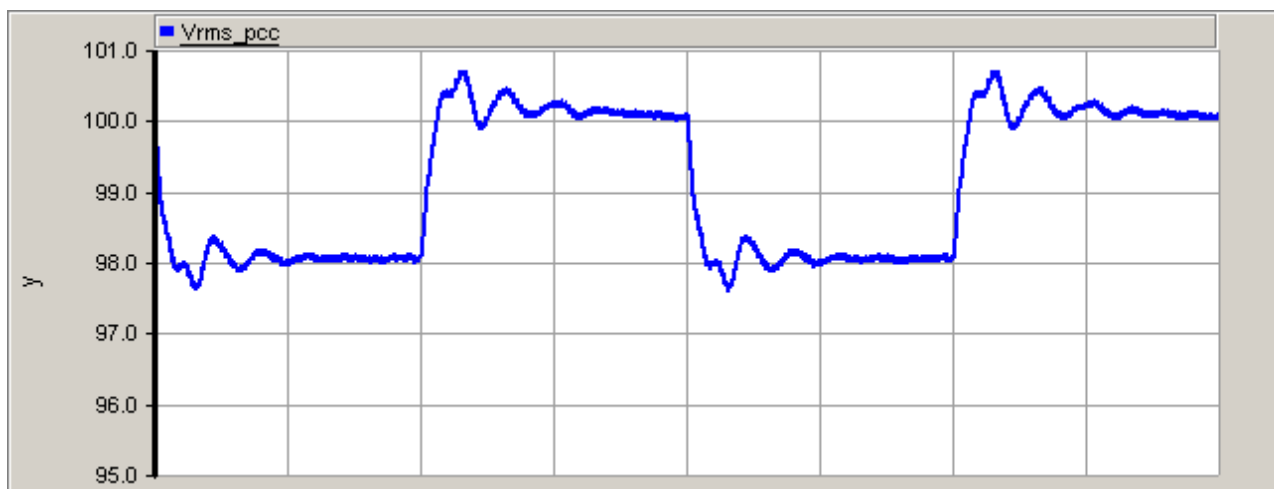
STATCOM reactive power control



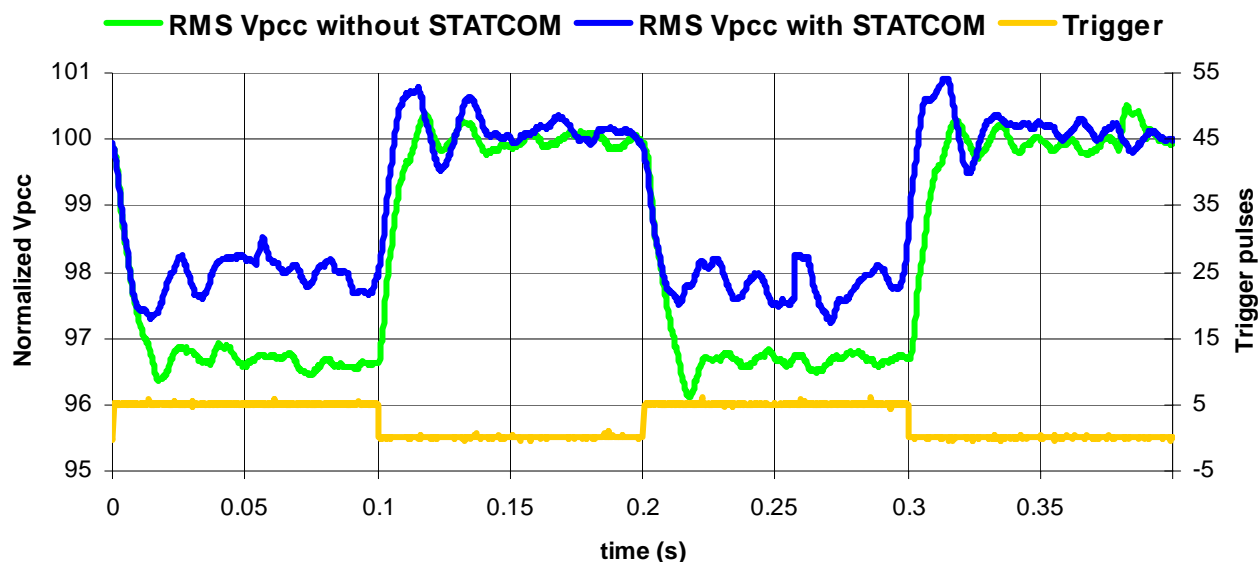
STATCOM/TUCAP independent reactive and active power control



Simulation:

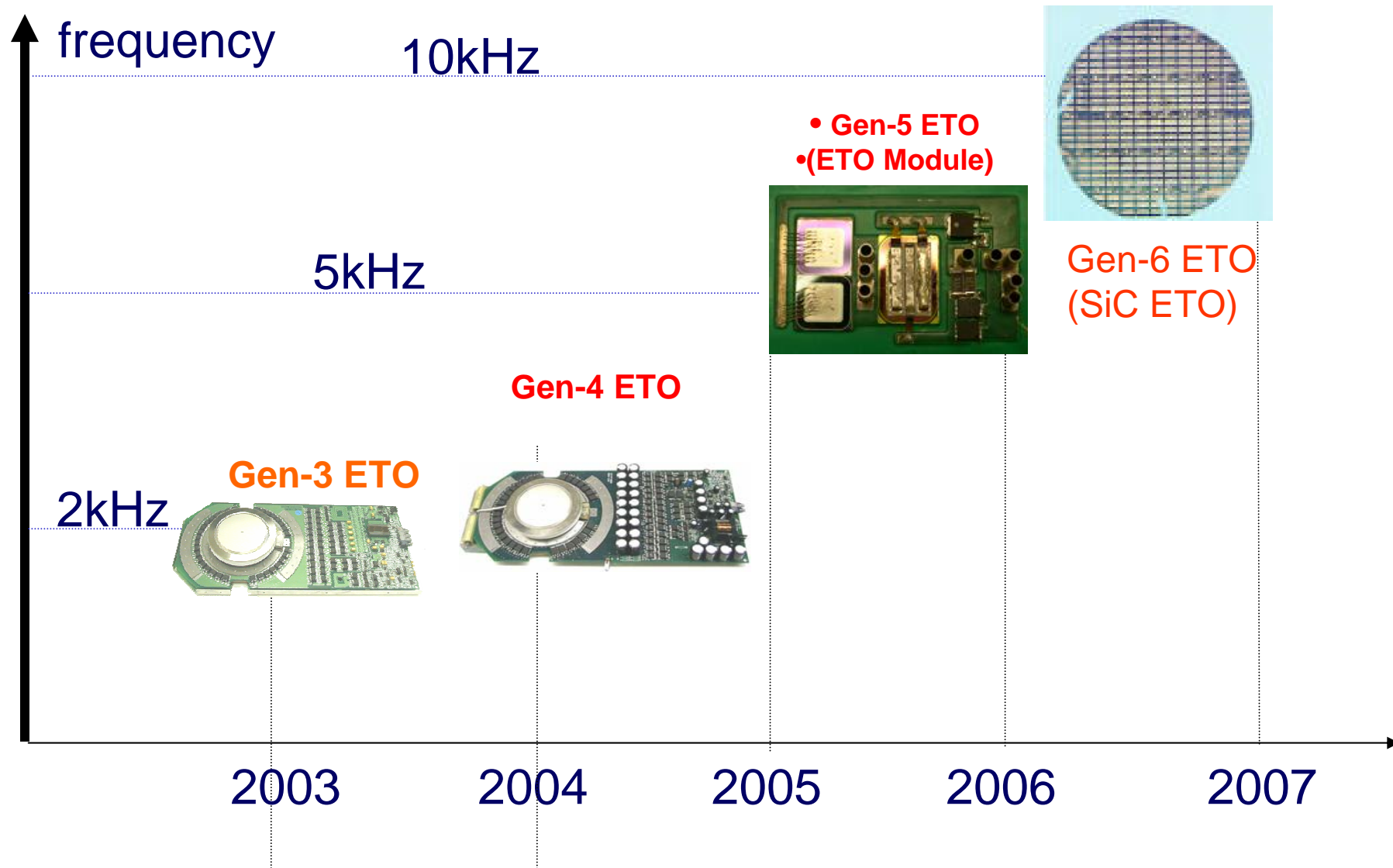


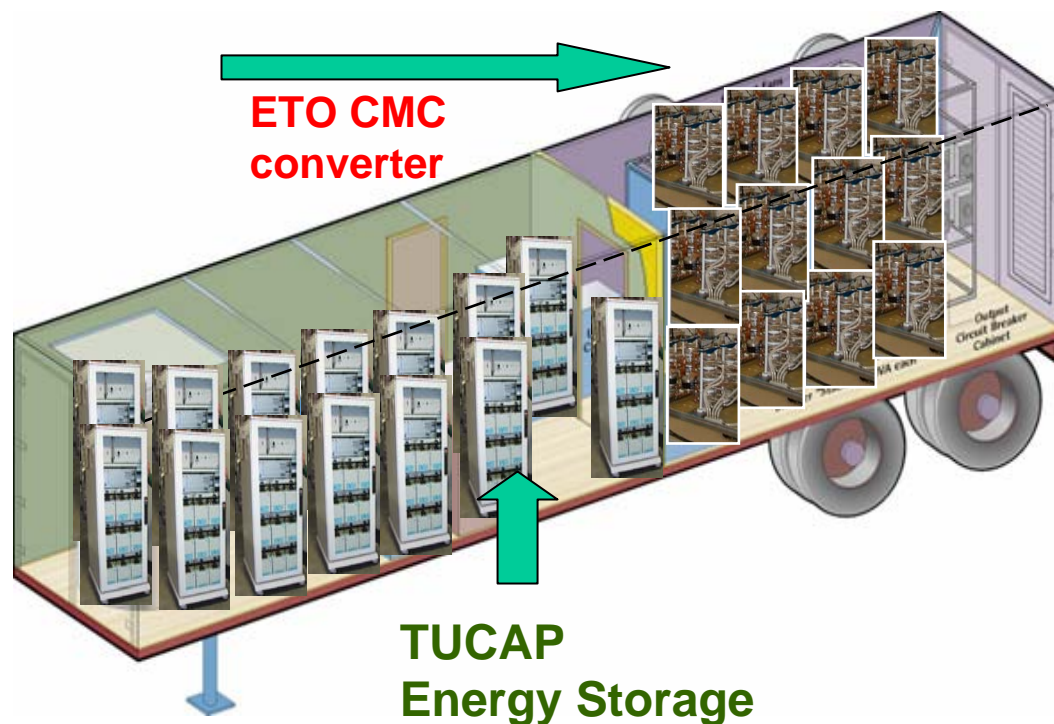
Experiment:



$X_s/R_s=3.7$, $Q_{statcom}/S_{load}=30\%$, 5Hz 3.2% flicker

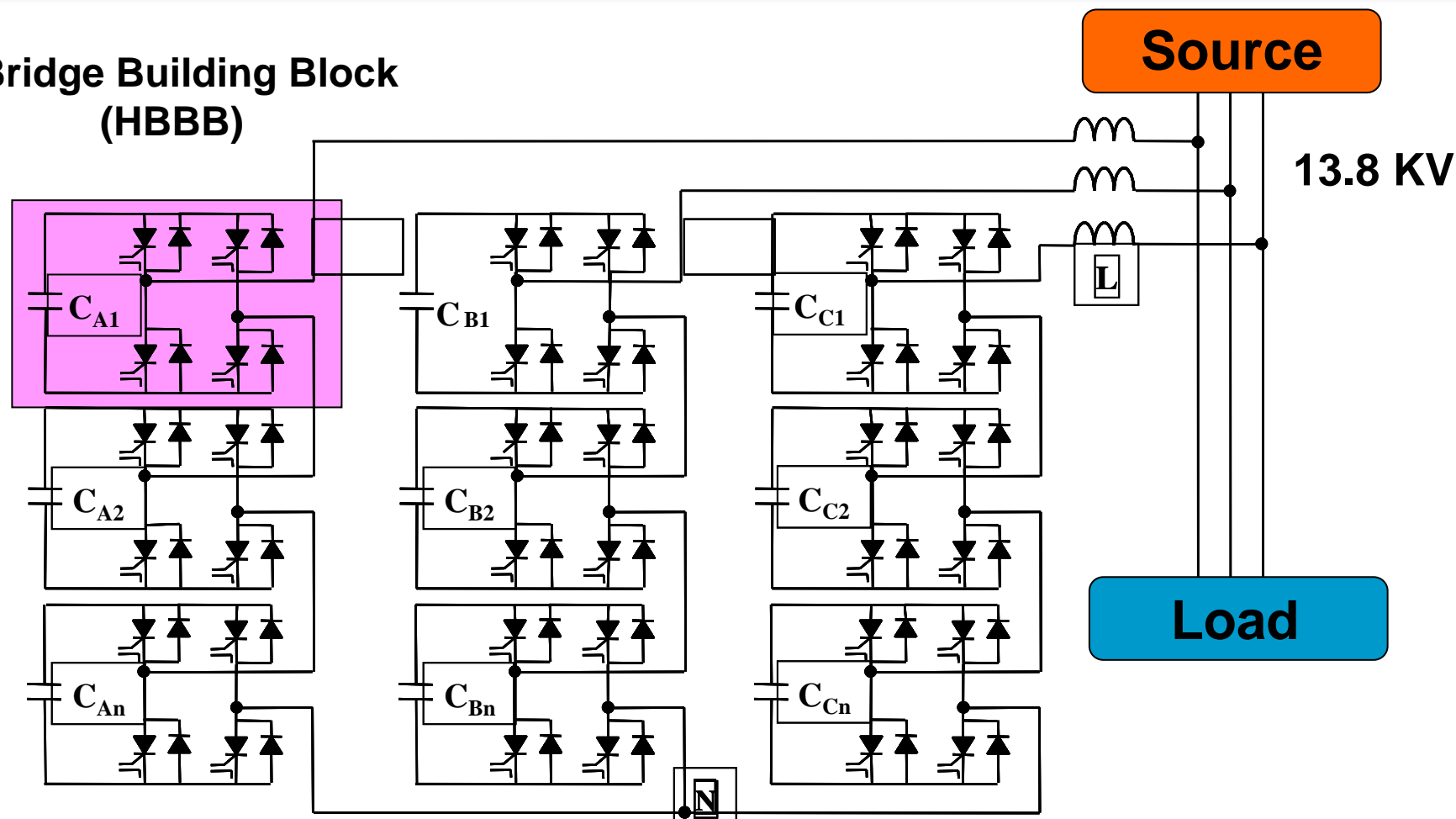
Future Plan: Demonstrate the Gen-4 and Gen-5 ETO in the TUCAP STATCOM





- 13.8 kV transformerless STATCOM/TUCAP
- Housed in one mobile trailer
- Placed close to customer
- Nominal 30 MVA, 60 MVA 2 second surge.
- \$60/ kVAr cost target

H-Bridge Building Block (HBBB)



- Cascaded multilevel voltage source converter using modular ETO HBBB
- System requirement: $\text{THD}_i < 2\%$, $V_{\text{AC_line}} = 13.8 \text{ kV}$

- New generations of ETO devices will significantly simplify the energy storage systems
 - Future development planned
- A 4.5 MVA ETO STATCOM/TUCAP system is being tested at SPEC Laboratory
- An Arc furnace flicker controller is being developed
- 30 MVA STATCOM/TUCAPO controller system is planned for future developed